A GENERAL SURVEY OF FOLIAR PESTICIDE RESIDUES AND AIR CONCENTRATION LEVELS FOLLOWING VARIOUS GREENHOUSE APPLICATIONS, 1986

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SUMMARY

Twenty seven pesticide applications were monitored in greenhouses from Monterey, San Mateo, and Santa Cruz Counties. Dislodgeable foliar residue and ambient air samples were collected at pre-determined intervals during and after benomyl, captan, chlorothalonil, endosulfan, fluvalinate, methomyl, methyl parathion (micro-encapsulated), oxamyl, permethrin, and triforine high-volume (HV) spray applications. Post-application air samples were also collected after one low-volume (LV) thermal pulse fogger application. In most cases, foliar residue levels did not exceed the estimated safe level at expiration of the reentry interval (if applicable). Air concentrations did not exceed 0.03 mg/m^3 during and 0.01 mg/m^3 immediately following HV applications. Air concentrations monitored at several intervals following the thermal pulse fogger application ranged from 0.012 to 3.14 mg/m^3 for chlorothalonil and 0.02 to 0.70 mg/m^3 for permethrin; pesticides were not detected after venting. Additional data are needed to determine potential pesticide exposure to workers in a greenhouse environment.

INTRODUCTION

Reentry intervals[1/] were originally determined using information from fieldworker illness cases. When additional data became available from sources such as laboratory dermal dose-response studies and field residue degradation studies, reentry intervals were revised. Therefore, the current reentry intervals which apply to both greenhouse and field applications may not provide appropriate protection in a greenhouse environment.

There are several factors unique to the greenhouse environment that may cause an increased potential hazard to pesticide applicators and employees working in currently or previously treated areas. Pesticide residue levels found in greenhouses may be potentially higher than those levels found in the field because commodities are treated on a frequent basis - monthly, weekly, and in some cases, on a daily schedule. In addition, application rates for ornamentals frequently exceed those rates for field grown crops.

Environmental conditions, such as high temperatures and humidity, may affect the degradation of surface pesticide residues. Furthermore, airborne residues may not readily dissipate from an enclosed greenhouse with limited ventilation.

The cultivation of most greenhouse-grown commodities is labor intensive. Since most cultural practices can not be mechanized, ornamental production requires excessive handling of plants on a daily basis. Many workers do not wear gloves or other protective gear, thus increasing potential contact with residues during cultural activities.

Worker Health and Safety (WH&S) personnel from the California Department of Food and Agriculture (CDFA) monitored 27 pesticide applications in attempt to gather general information on the deposition and the subsequent behavior of residues in a greenhouse environment. Air and foliage samples were collected during and after applications of insecticides and fungicides frequently used in the greenhouses. These data will be used to design subsequent studies involving worker exposure to pesticides in greenhouses.

MATERIALS AND METHODS

Studies were conducted in commercial greenhouses located in several central coast counties of California. Cooperators were contacted with assistance from the staff of local county agricultural commissioner. Each grower supplied a list of insecticides and fungicides frequently used in their operations. Emphasis was on restricted use pesticides, and pesticides for which a reentry interval is required. Benomyl, captan, chlorothalonil, endosulfan, fluvalinate, methomyl, methyl parathion (micro-encapsulated formula), oxamyl, permethrin, and triforine applications to foliage plants, flower stock, and cut flowers were monitored.

1/ Reentry interval is the period of time that must elapse between a pesticide application and the entry of unprotected workers into the treated area to conduct activities that may involve substantial body contact with treated foliage.

Foliage samples for dislodgeable residues were collected from high volume applications; ambient air samples were collected from high volume applications and a thermal pulse fogger (Pulsfog^R) application.

High Volume Applications:

APPLICATION INFORMATION: In most greenhouses, a hand-held application wand was used. This wand was attached to hosing which was connected to a mobile or stationary spray unit located within the greenhouse treatment area or in an area adjacent to the greenhouse. Plumbing systems located throughout the greenhouse provided spray wand connections to the stationary unit. Several different types of spray wands were employed. The following wand designs were used for the monitored applicatons:

a. A spray wand that consisted of either a large nozzle with many apertures or a cluster of four to six nozzles, both located at the end of the wand, was used by potted plant and cut flower growers.

b. A Japanese manufactured spray wand referred to as a "Karu Pole" was used by several cut flower growers. This design consisted of a single nozzle located at the tip of the wand with a second nozzle appoximately six inches from the first nozzle. Each nozzle had three openings.

c. A third type of spray wand was comprised of four large nozzles located at equal distances on a three foot long pole. Each nozzle had 10 to 20 openings. This wand, which is designed to spray the entire width of a bench, was used primarily by flower stock growers.

Spray material was applied at various pressures ranging from 140-300 pounds per square inch (psi). The applicator moved down each bench or row thoroughly covering the plants, and in many cases, spraying the plant until dripping wet with dilute material.

Approximate rates in pounds of active ingredient per acre (lbs AI/A) of treated area (including bench and alley area) were calculated using total amount of spray material applied and the approximate square footage of the treated area. The actual rate in lbs AI/100 gallons of water is also given for each treatment; both rates are presented in Appendix I.

Greenhouse environmental conditions were recorded throughout the entire monitoring period. Variables included temperature, relative humidity, light intensity, air movement (type of ventilation), and irrigation schedules (drip, overhead sprinklers, etc.). In addition, a description of the greenhouse structure and bench arrangement was noted.

DISLODGEABLE FOLIAR RESIDUES: Surface pesticide residues were determined using leaf samples collected from several points within the treatment area. A general sampling strategy was used to determine areas for leaf collection. Three sections where chosen to approximate a diagonal or an equal distribution across the treatment area. A sample consisted of leaf disks collected from one or two benches selected from each section. Triplicate samples were collected at each sampling interval. Foliage (except carnation) was collected with a Birkestrand leaf punch (2.54 or 1.25 centimeter diameter) using the methods similar to those described by Iwata et al. (1). The 2.54 centimeter diameter punch was used for commodities having larger leaves such as chrysanthemums and roses. The smaller diameter punch (1.25 cm) was reserved for plants with smaller leaves which could not accommodate the larger size punch. Leaf disks were accumulated in a four ounce jar attached to the leaf punch device. A minimum of 40 disks (13-14 disks per bench) were collected per sample. Sample size for each application was determined by the amount of available foliage, and the amount of plant material needed for an accurate analysis.

Carnation leaves were too thin for collection with either size leaf punch, therefore another method was employed. Leaves were cut off at the petiole and dropped directly into a four ounce jar. Care was taken to avoid dislodgement of the residue. One sample contained approximately equal amounts of foliage from the three sampling areas. Each sample was weighed and the leaf surface area was calculated based on a pre-determined weight to surface area ratio.

After collection, sample jars were capped and packed on wet ice for shipment to the California Department of Food and Agriculture (CDFA) Chemistry Services in Sacramento. Dislodgeable residue samples were extracted within 24 hours when possible. Samples collected over a weekend were analyzed within 48 hours. Analytical methods for dislodgeable residues are presented in Appendix II.

The sampling schedule varied with each application. Generally, foliage samples were collected at the following intervals:

Pre-application
Within 1 - 3 hours post application (PA)
21 - 23 hours PA
24 hours PA
One sample after 24 hours and prior to 48 hours PA.

If a reentry interval longer than 24 hours was required for a particular pesticide application, samples were collected daily until the reentry interval expired.

CARNATION WEIGHT TO SURFACE AREA ESTIMATES: Tweleve carnation foliage samples of varing weights were collected and used to determine a weight to surface area relationship. Each sample was passed through a leaf area meter three times. The three values were averaged then doubled to represent the total upper and lower leaf surface areas. Straight line regression analysis was applied to the surface areas and corresponding weights. The resutling equation was:

$$y = 37.953x - 4.839; \quad (r = 0.998)$$
x = weight in grams
y = surface area

AMBIENT AIR SAMPLES: Greenhouse air was sampled by drawing air through a media sampling train attached to a MSA (Fixt-Flo, Model 1) personal air pump. Flow rates ranged from 1.0 to 2.5 liters per minute; 70 and 270 liters of air were collected at each sampling period. Pumps were fitted with a sampling train consisting of a sorbent sampling tube attached to a filter housed in a cassette holder. Sampling media used for each pesticide are presented in Appendix III. Air pumps were calibrated with a Kurz 540S Mass Flow Meter before and after each sampling period.

Four or six sites were selected within the treatment area for pump placement. The number of sites was dependent on the size of the treatment area and availability of equipment. Pre-application, during application, and immediate post-application samples were collected. Monitoring periods lasted for approximately one hour before the application, 0.75 to 3 hours during application, and 1 to 2 hours post-application. Samples were stored on wet or dry ice and shipped to Chemistry Services for analysis. Analytical methods are presented in Appendix II.

Low Volume Application

Air within the greenhouse was monitored for 17 hours following a thermal pulse fogger application. Chlorothalonil and permethrin were applied at the rates of 0.39 lbs AI and 0.50 lbs AI, respectively, for the 10,000 ft^3 of enclosed greenhouse area. MSA personal air pumps were placed at four sites within a 50 foot radius of the thermal pulse fogger. The pump inlets were fitted with a sampling train consisting of a glass fiber filter (GFF-A, 0.2 um) followed by a chromosorb 102 sorbent tube. Air samples were collected pre-application (1 hour sampling period); 1 to 2 hours, 2 to 3 hours, 13.5 to 14 hours, and 16 to 17 hours post-application. The greenhouse was fully vented prior to the last sampling period. Ambient air temperatures were recorded during the monitoring periods.

RESULTS

Survey results are summarized in Tables I through XI. High volume spray applications are presented by pesticide (Tables I - X); low volume thermal pulse fogger application results are presented in Table XI. Dislodgeable foliar residues are given in micrograms of residue per square centimeter of leaf surface (ug/cm^2). Foliar residue levels given for each sampling interval are the mean value and standard deviation of three replicate samples. Airborne residue levels are given in milligrams of residue per cubic meter of air (mg/m^3); values are given for each air sampling location.

DISCUSSION AND CONCLUSIONS

Pesticide dissipation rates are affected by several environmental conditions unique to greenhouses. Structural designs influence the overall environment within each house. Houses can be constructed using glass, fiberglass, polyvinyl sheeting or rigid acrylic. Each of these materials allow for varying degrees of light transmission. In addition, walls and ceilings may be removed or whitewashed, also altering light transmission. Opaque tarps are often used to regulate the photoperiod for some crops such as poinsettias and chrysanthemums. This method eliminates all light for specific time periods during the day. Waldron (3) found air concentrations of some pesticides, such as captan, were affected by the presence or absence of sunlight. Although light intensity was not investigated during CDFA studies, this factor could account for variability in monitoring results.

Ventilation systems vary greatly with each greenhouse design. System designs range from passive ventilation using wall and ceiling vents to mechanical ventilation using fans in conjunction with elaborate venting systems. Airborne residues were found prior to two applications. Benomyl and captan airborne residues were found prior to and during an application in a greenhouse with passive ventilation. Since residues were not found in post-application air samples, pre-application residues levels were most likely due to sample media contamination (Table I and II). In contrast, chlorothalonil airborne residues were found prior to, during, and after an application in a greenhouse equipped with mechanical ventilation (the fans were not functioning during the monitoring period). In addition, foliar residue samples collected before and after this application contained levels considerably higher than those levels found after a similar application in the same greenhouse (Table III).

Heating systems may also be incorporated with ventilation systems. Climatic conditions such as temperature and humidity are subsequently affected by the type and amount of ventilation. Conditions of high humidity enhance pesticide penetration into the leaf by favoring stomatal opening. High humidity also slows the drying of spray deposits allowing more time for absorption (4). As a result, absorption of foliar surface residues is greatly affected by humidity and ambient temperatures which are altered dramatically by different ventilation practices.

Dissipation of surface foliar residues varied between each pesticide and each application monitored. Frequently growers will apply restricted use pesticides over the weekend to avoid exposure to workers in adjacent houses. Therefore, post-application foliage samples were collected on Friday or Saturday then stored for over 24 hours prior to analysis. As a result, surface foliar residues may have degraded or penetrated the leaf surface during the extended storage period. In some cases, residues detected in samples collected on the weekend were considerably lower than those levels found in subsequent samples (see Table II Application III; Table IX Application I).

Pesticide deposition and dissipation may also be affected by application rates, dilution rates, application methods, and frequency of the treatments. The size of the treatment area, amount and density of plant material in that area, and the physical characteristics of each commodity should also be considered.

Dislodgeable foliar residues were below the estimated safe level(s) (for those pesticides with estimated safe levels) at the expiration of the reentry interval for most of the applications monitored. Residue levels following a methomyl, and a methyl-parathion (micro-encapsulated) application exceeded the safe level at the end of the reentry interval. In the case of the methomyl application, a small section of chrysanthemum stock had been treated on a weekly basis prior to monitoring. Foliage samples collected after the forth methomyl application contained 5.27 ug/cm^2 at expiration of the 48-hour reentry interval [current estimated safe level is 1.5 ug/cm^2 (5)] (Table VI Application II). Under field conditions, methomyl degrades rapidly; the half-life on leafy vegetables averages two days (6). However, methomyl has been found to build up on the fruit of greenhouse grown tomatoes after three weekly applications (7).

Monitoring results completed after a methyl-parathion application identified high levels of dislodgeable residue on chrysanthemum stock at expiration of the five day reentry interval. Residue levels were 1.37 ug/cm^2, which is 0.77 ug/cm^2 over the estimated safe level of 0.60 ug/cm^2 (Table VII, Application I). Laboratory methods allow for analysis of all methyl-parathion including pesticide still bound in capsules. Theoretically, methyl-parathion bound in capsules is not available for exposure to workers (8). Therefore, dislodgeable residues detected after this application may not be completely available to the worker.

Pesticide residues recovered from air sampling media (filter and sorbent tubes) indicate that levels during and after high volume spray applications are very low. After a thermal pulse fogger application, airborne pesticide residues dissipated slowly while the greenhouse remained closed. Chlorothalonil air concentrations ranged from 2.583 to 3.495 mg/m^3 during the one to two hour post-application sampling period; permethrin concentrations ranged from 0.611 to 0.826 mg/m^3 during this same period. Chlorothalonil and permethrin air levels decreased 35 percent and 15 percent, respectively, during the two to three hour post-application sampling period. The greenhouse remained closed (no ventilation) up to 14 hours post-application at which time chlorothalonil concentrations ranged from 0.010 to 0.016 mg/m^3 and permethrin concentrations ranged from 0.37 mg/m^3 to a non-detectable level (below 0.007 mg/m^3). Neither chlorothalonil nor permethrin were detected in air samples collected after the greenhouse was vented for two hours (Table XI; 16 to 17 hours post-application). Airborne residues were either not detected or found at low levels during and following high volume applications. Other investigators found similar residual dissipation after low volume and high volume applications (3).

In conclusion, a direct comparison of foliar or air residue levels can not be examined because different field and application conditions between greenhouses must be considered.

HIGH VOLUME APPLICATIONS (TABLES I-X)

TABLE I: Benomyl Airborne Residues and Mean Concentrations of Benomyl Dislodgeable Residues.

APPLICATION I. Carnations (cut flowers): 0.5 lb AI/100 gal; **1 lb AI/Acre**

Foliar Residues:

Sample Time	ug/cm2
Pre-application	0.47 ± 0.15
1 Hour post-application1/	1.38 ± 0.49
10 Hour post-application	1.24 ± 0.16
4 Days post-application	0.94 ± 0.21
5 Days post-application	0.63 ± 0.27

Airborne Residues:

Sample Time	MG/M3 A	B	C	D	E	F
Pre-application	0.034	ND2/	ND	ND	0.073	ND
During application	0.016	0.013	0.010	-	0.049	0.012
Post-application		ND; MDL = 0.008 - 0.010				

1/ Plants were wet during sample collection.
2/ None detected; minimum detectable level = 0.015 - 0.016 mg/m^3

TABLE II: **Captan Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Three Applications.**

APPLICATION I. Carnations (cut flowers): 1 lb AI/100 gal; 2 lbs AI/Acre

Foliar Residues:

Sample Time	ug/cm^2		
Pre-application	0.29	±	0.18
1 Hour post-application[1/]	4.98	±	0.54
10 Hours post-application	4.33	±	0.64
4 Days post-application	3.26	±	0.31
5 Days post-application	2.38	±	0.70

1/ Plants were wet during sampling.

Airborne Residues:

	mg/m^3					
Sample Time	A	B	C	D	E	F
Pre-application	ND[2/]	ND	ND	ND	ND	0.011
During application	0.007	0.004	0.005	-	0.002	0.003
Post-application	ND[3/]	ND	ND	ND	ND	0.003

2/ None detected; minimum detectable level = 0.003 mg/m^3
3/ None detected; minimum detectable level = 0.002 mg/m^3

APPLICATION II. Carnation (stock): 0.75 lbs AI/100 gal.; 1.88 lbs AI/Acre

Foliar Residues:

Sample Time	ug/cm^2		
Pre-application[4/]	5.89	±	0.36
Immediate Post-application	9.56	±	1.02
1 Hour Post-application	7.00	±	1.17
24 Hours Post-application	6.85	±	0.79
48 Hours Post-application	7.10	±	0.53

4/ Previous captan applications 7 and 14 days prior to sampling.

Airborne Residues:

No captan detected in samples; minimum detectable levels were 0.010 mg/m^3 pre-application, 0.003-0.004 mg/m^3 during application, 0.006 mg/m^3 post-application.

TABLE II: (cont.)

APPLICATION III. Roses: 1.25 lbs AI/100 gal.; 5 lbs AI/Acre

Foliar Residues:

Sample Time	ug/cm^2
Pre-application	0.06 ± 0.07
Immediate post-application[5/]	2.79 ± 0.02
7 Hours post-application[5/]	2.95 ± 0.30
21 Hours post-application	3.84 ± 0.08
24 Hours post-application	3.25 ± 0.25

[5/]Samples were stored on wet ice for 48 hours prior to analysis.

Airborne Residues:

No captan detected in samples; minimum detectable levels were 0.009 mg/m^3 pre-application, 0.004 mg/m^3 during application, 0.009 mg/m^3 post-application.

TABLE III: Chlorothalonil Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Three Applications.

APPLICATION I. Carnation (stock): 1.05 lbs AI/100 gal.; 2.4 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application[1/]	4.07 ± 1.78
0.5 Hour post-application	10.46 ± 1.94
1 Hour post-application	9.87 ± 1.54
24 Hours post-application	5.11 ± 0.93
48 Hours post-application	4.80 ± 1.72

[1/] Application 6 days prior to sampling.

B. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	ND[2/]	0.001	0.002	0.002
During application	0.044	0.025	0.036	0.029
Post-application	0.003	0.003	0.001	0.002

[2/] None detected; minimum detectable level = 0.005 mg/m^3

APPLICATION II. Carnation (stock): 1.05 lbs AI/100 gal.; 2.4 lbs AI/Acre

A. Foliar Resiudes:

Sample Time	ug/cm^2
Pre-application[3/]	0.25 ± 0.08
3 Hours post-application	2.30 ± 0.34
24 Hours post-application	2.65 ± 0.87

[3/] Previous applications 34 days, 60 days, and 66 days prior to sampling.

B. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	ND[4/]	ND	ND	ND
During application	0.002	0.001	0.004	0.001
Post-application	ND[5/]	ND	ND	ND

[4/] None detected; minimum detectable level = 0.008 mg/m^3
[5/] None detected; minumum detectable level = 0.007 mg/m^3

TABLE III: (cont.)

APPLICATION III. Carnation (Stock): 1.04 lbs AI/100 gal; 2.4 lbs AI/Acre

A. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	ND[6/]	ND	ND	ND
During application	0.009	0.006	0.016	0.008
Post-application	ND[7/]	ND	ND	ND

6/ None detected; minimum detectable level = 0.021 mg/m^3
7/ None detected; minimum detectable level = 0.009-0.010 mg/m^3

TABLE IV: Endosulfan I and II* Airborne Residues and Mean Concentrations of Dislodgeable Residues for Three Applications.

APPLICATION I. Carnation Stock: 0.5 lb AI/100 gal.; 1.25 lbs AI/Acre (Wettable powder).

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	
Endosulfan I	None Detected 1/
Endosulfan II	None Detected
Immediate post-application	
Endosulfan I	1.99 ± 0.22
Endosulfan II	0.71 ± 0.09
1 Hour post-application	
Endosulfan I	1.33 ± 0.21
Endosulfan II	0.48 ± 0.09
24 Hours post-application	
Endosulfan I	0.84 ± 0.16
Endosulfan II	0.46 ± 0.04
48 Hours post-applicaiton	
Endosulfan I	1.05 ± 0.15
Endosulfan II	0.67 ± 0.06

1/ Minimum detectable level = 0.001 ug/cm^2 each.

B. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	ND 2/	ND	ND	ND
During application				
Endosulfan I	0.001	0.002	0.0002	ND
Endosulfan II	0.0004	0.0007	0.0004	ND
Post-application				
Endosulfan I	0.001	0.001	ND	
Endosulfan II	ND	ND	ND	

2/ None detected; minimum detectable level for
- pre-application = 0.0004 mg/m^3
- during application = 0.0004 mg/m^3
- post application = 0.0002 mg/m^3

* Endosulfan stereo isomers are referred to as Endosulfan I and II. All samples were analyzed for endosulfan sulfate, the compound was not detected in any sample.

TABLE IV: (cont.)

APPLICATION II. Cyclamen: 0.49 lbs AI/100 gal.; 1.23 lbs AI/Acre
(emulsifiable concentrate)

A. Foliar Residues:

Sample Time	ug/cm2		
Pre-application			
Endosulfan I	None Detected3/		
Endosulfan II	None Detected3/		
1 Hour post-application			
Endosulfan I	0.24	±	0.006
Endosulfan II	0.16	±	0.03
22 Hours post-application			
Endosulfan I	0.17	±	0.05
Endosulfan II	0.16	±	0.04
42 Hours post-applicaiton			
Endosulfan I	0.11	±	0.04
Endosulfan II	0.12	±	0.04
72 Hours post-application			
Endosulfan I	0.06	±	0.01
Endosulfan II	0.08	±	0.004

3/ Minimum detectable level = 0.002 ug/cm^2

B. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	ND4/	ND	ND	ND
During application				
Endosulfan I	0.006	0.005	0.009	0.008
Endosulfan II	0.015	ND4/	0.008	0.014
Post-application				
Endosulfan I	0.002	0.003	0.004	0.003
Endosulfan II	0.004	0.003	0.004	0.004

4/ None detected; minimum detectable level 0.0007-0.0009 mg/m^3 each.

TABLE IV: (cont.)

APPLICATION III. Mum Stock: 1 lb AI/100 gal.; rate per acre unknown. (wettable powder)

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	
Endosulfan I	None Detected[5/]
Endosulfan II	0.008 ± 0.001
2 Hours post-application[6/]	
Endosulfan I	1.02 ± 0.11
Endosulfan II	0.79 ± 0.08
6 Hours post-application	
Endosulfan I	0.92 ± 0.20
Endosulfan II	0.76 ± 0.19
9 Hours post-application	
Endosulfan I	0.95 ± 0.16
Endosulfan II	0.91 ± 0.14
25 Hours post-applicaiton	
Endosulfan I	0.87 ± 0.25
Endosulfan II	1.01 ± 0.34
32 Hours post-application	
Endosulfan I	0.88 ± 0.10
Endosulfan II	1.22 ± 0.30
48 Hours post-application	
Endosulfan I	0.38 ± 0.12
Endosulfan II	0.63 ± 0.16
55 Hours post-applicaiton	
Endosulfan I	0.28 ± 0.06
Endosulfan II	0.68 ± 0.10

5/ Minimum detectable level = 0.003 ug/cm^2
6/ Plants were wet during sampling.

B. Airborne Residues:

No endosulfan I and II detected in air samples; MDLs were 0.0009 mg/m^3 each pre-application; 0.001 mg/m^3 each during application; and 0.0006 each post application.

TABLE V: Fluvalinate Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Three Applications.

APPLICATION I. Carnation (Stock): 0.061 lbs AI/100 gal.; 0.145 lbs/Acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application1/	0.004	±	0.001
Immediate post-application	0.099	±	0
1 Hour post-application	0.091	±	0.013
24 Hours post-application	0.050	±	0.017
48 Hours post-application	0.057	±	0.019

1/ Previous application 6 days prior to sampling.

B. Airborne Residues:

No fluvalinate detected (MDL = 0.0004 - 0.0005).

APPLICATION II. Gerbera Daisy (Potted Plant): 0.047 lbs AI/100 gal.; 0.034 lbs AI/A

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application	None detected2/		
1 Hour post-application	0.0055	±	0.0002
5 Hours post-application	0.0039	±	0.0010
22 Hours post-application	0.0044	±	0.0002
27 Hours post-application	0.0056	±	0.0028

2/ Minimum detectable level = 0.002 ug/cm^2

B. Airborne Residues:

No Fluvalinate detected (MDL = 0.002 - 0.012 mg/m^3).

APLICATION III. Carnations (Cut Flowers); 0.10 lbs AI/100 gal.; 0.031 lbs AI/Acre

A. Foliage

Sample Time	ug/cm^2		
Pre-application		ND3/	
1 Hour post-application4/	0.030	±	0.006
10 Hours post-application	0.022	±	0.003
4 Days post-application	0.015	±	0.003
5 Days post-application	0.008	±	0.003

3/ None detected; minimum detectable level = 0.0015 ug/cm^2
4/ Plants were wet during sampling.

TABLE VI: Methomyl Airborne Residues and Mean Concentrations of Dislodgeable Residues for Five Applications.

APPLICATION I. Mum (Potted Plants): 0.45 lbs AI/100 gal.; approxiamtely 2.25 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm2		
Pre-application1/	0.08	±	0.02
Immediate post-application	1.64	±	0.13
17 Hours post-application	1.79	±	0.08
24 Hours post-application	0.76	±	0.13
42 Hours post-application	0.74	±	0.10

1/ Previous application was 14 days prior to sampling.

B. Airborne Residues:

Sample Time	mg/m3 A	B	C	D
Pre-application	None detected2/			
During applicaiton	0.024	0.039	0.055	0.044
Immediate post-application	0.006	0.006	0.006	ND3/

2/ Minimum detectable level = 0.0019 mg/m^3
3/ Minimum detectable level = 0.003 mg/m^3

APPLICATION II. Mum Stock: 0.34 lbs AI/100 gal.; approximately 2.7 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm2		
Pre-application4/	Not Available		
Immediate post-application	10.81	±	3.25
6 Hours post-application	10.28	±	3.70
24 Hours post-application	8.32	±	0.10
48 Hours post-application	5.27	±	0.38
72 Hours post-application	2.17	±	0.60

4/ Methomyl applications were made 7, 14, and 21 days prior to this application.

5/ Methomyl found in samples but quantity is unknown.

TABLE VI: (cont.)

APPLICATION III. Mum (Potted Plant): 0.34 lbs AI/100 gal.; 2.03 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	ND[6/]
3 Hours post-application[7/]	1.70 ± 0.17
7 Hours post-application	1.41 ± 0.10
24 Hours post-application	1.12 ± 0.12
48 Hours post-application	0.92 ± 0.04

6/ None detected; minimum detectable level = 0.005 ug/cm^2
7/ Plants were wet during sample collection.

B. Airborne Residues:

No methomyl detected in samples; minimum detectable levels were 0.013 -0.089 mg/m^3.

APPLICATION IV. Mum (Potted Plant): 0.34 lbs AI/100 gal.; rate per acre unknown

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	ND[8/]
13 Hours post-application	0.35 ± 0.03
20 Hours post-application	0.27 ± 0.11
39 Hours post-application	0.26 ± 0.09
3 Days post-application	0.19 ± 0.15
4 Days post-application	0.20 ± 0.07

8/ None detected; minimum detectable level = 0.012 ug/cm^2

B. Airborne Residues:

	mg/m^3			
Sample Time	A	B	C	D
Pre-application	ND[9/]	ND	ND	ND
During application	0.003	0.005	0.005	0.003
Immediate post-application	ND[9/]	ND	0.003	ND

9/ None detected; minimum detectable level = 0.003 mg/m^3

TABLE VI: (cont.)

APPLICATION V. Mums (Potted Plants): 0.34 lbs AI/100 gal.; 1.36 lbs/Acre.

A. Foliar Residues:

Sample Time	ug/cm²		
Pre-application	ND[10/]		ND
13 Hours post-application	0.23	±	0.10
20 Hours post-application	0.28	±	0.11
38 Hours post-application	0.29	±	0.05
44 Hours post-application	0.22	±	0.02
62 Hours post-application	0.19	±	0.05
71 Hours post-application	0.15	±	0.01

10/ None detected; minimum detectable level = 0.0005 ug/m^3

B. Airborne Residues:

	mg/m^3			
Sample Time	A	B	C	D
Pre-application	ND[11/]	ND	ND	ND
During application	0.010	0.009	0.007	0.007
Immediate applicaiton	ND[12/]	ND	ND	ND

11/ None detected; minimum detectable levels = 0.007-0.009 mg/m^3

12/ None detected; minimum detectable levels = = 0.004 mg/m^3

TABLE VII: Micro-encapsulated Methyl Parathion Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Three Applications.

APPLICATION I. Mums Stock: 0.25 lbs AI/100 gal.; 0.40 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	ND1/
24 Hours post-application	2.14 ± 0.16
48 Hours post-application	1.66 ± 0.23
3 Days post-application	1.22 ± 0.20
4 Days post-application	1.33 ± 0.17
5 Days post-application	1.37 ± 0.14

1/ None detected; minimum detectable level = 0.003 ug/cm^2

B. Airborne Residues:

Sample Time	A	B	C	D	E	F
			mg/m^3			
Pre-application			None Detected1/			
During application	0.005	0.003	0.003	0.004	ND3/	ND4/
Post-application	0.002	ND5/	ND5/	0.003	ND5/	-

2/ Minimum detectable level = 0.01 mg/m^3
3/ None detected; minimum detectable level = 0.009 mg/m^3
4/ None detected; minimum detectable level = 0.007 mg/m^3
5/ None detected; minimum detectable level = 0.011 mg/m^3

APPLICATION II. Mums (Potted Plants): 0.25 lbs AI/100 gal.; 0.87 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2
Pre-application	ND6/
13 Hours post-application	0.83 ± 0.10
20 Hours post-application	0.65 ± 0.10
39 Hours post-application	0.56 ± 0.09
3 Days post-application	0.53 ± 0.11
4 Days post-application	0.38 ± 0.15

6/ None detected; minimum detectable level = 0.005 ug/cm^2

B. Foliar Residues:

No methyl parathion detected; minimum detectable levels ranged from 0.001-0.004 mg/m^3.

III. Mums (Potted Plants): 0.25 lbs AI/100 gal.; 0.55 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application		ND[7/]	
1 Hour post-application	0.77	±	0.21
20 Hours post-application	0.43	±	0.02
26 HOurs post-application	0.50	±	0.03

[7/] None detected; minimum detectable level = 0.0005 ug/cm^2

TABLE VIII: Oxamyl Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for One Application.

APPLICATION I. Mums (Cut Flowers): 0.5 lbs AI/100 gal.; 2.17 lbs AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application		ND[1]	
Immediate post-application[1]	1.07	±	0.07
5 Hours post-application	1.61	±	0.24
21 Hours post-application	1.08	±	0.13
33 Hours post-application	0.76	±	0.22

1/ None detected; minimum detectable level = 0.001 ug/cm^2
2/ Leaves were wet during sample collection.

B. Airborne Residues:

	mg/m^3			
Sample Time	A	B	C	D
Pre-application		None detected[3]		
During application	0.039	0.032	0.017	0.014
Post-application	0.004	0.004	0.004	0.004

3/ Minimum detectable level = 0.0045 mg/m^3

TABLE IX: Permethrin Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Two Applications.

APPLICATION I. Mums (Potted Plants): 0.20 lbs AI/100 gal.; 0.4 lbs AI/$\frac{1}{8}$ - $\frac{1}{4}$ acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application1/	0.23	±	0.04
Immediate post-application2/	0.47	±	0.11
17 Hours post-application2/	0.54	±	0.15
24 Hours post-application	0.74	±	0.03
42 Hours post-application	0.66	±	0.13

1/Last application was 14 days prior to sampling.
2/Samples were stored on wet ice for 48 hours prior to analysis.

B. Airborne Residues:

Sample Time	mg/m^3 A	B	C	D
Pre-application	None detected3/			
During application	0.035	0.042	0.075	0.090
Post-application	None detected4/			

3/ Minimum detectable level = 0.0047 mg/m^3
4/ Minimum detectable level = 0.0061-0.0063 mg/m^3

APPLICATION II. Mums (Potted Plants): 0.20 lbs AI/100 gal.; rate per acre unknown.

A. Foliar Residues:

No samples collected.

B. Airborne Residues:

No permethrin detected; minimum detectable levels ranged from 0.0244 - 0.0323 mg/m^3.

TABLE X: Triforine Airborne Residues and Mean Concentrations of Dislodgeable Foliar Residues for Two Applications.

APPLICATION I. Roses (cut flowers): 0.15 lb AI/100 gal; 0.63 lb AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application	0.09	+	0.01
Immediate post-application	0.14	+	0.06
7 Hours post-application	0.17	+	0.02
21 Hours post-application	0.23	+	0.06
24 Hours post-application	0.25	+	0.09
27 Hours post-application	0.26	+	0.10

B. Airborne Residues: No triforine detected in samples; minimum detectable levels ranged from 0.14-0.033 mg/m^3.

APPLICATION II. Roses (cut flowers): 0.225 lbs AI/100 gal; approximately 0.45 lbS AI/Acre

A. Foliar Residues:

Sample Time	ug/cm^2		
Pre-application		ND1/	
0.5 Hours post-application	0.09	±	0.03
4 Hours post-application	0.13	±	0.03
7 Hours post-application	0.71	±	0.05
23 Hours post-application	0.66	±	0.08
30 Hours post-application	0.53	±	0.07

1/ None detected; minimum detectable level = 0.007 ug/cm^2

B. Airborne Residues:

No triforine detected in samples; minimum detectable levels ranged from 0.0028 - 0.0037 mg/m^3

TABLE XI: Airborne Chlorothalonil and Permethrin Residues Detected After a Thermal Pulse-Fog Application.

A. Chlorothalonil: 0.39 lb AI/10,000 ft^3

Hours Post Application	A	B	C	D
		mg/m^3		
Pre-application		None Detected 1/		
1 to 2 Hours post-application	3.005	3.489	3.495	2.583
2 to 3 Hours post-application	1.747	2.141	2.027	2.006
13.5 to 14 Hours post-application	0.010	0.016	0.010	0.011
16 to 17 Hours 2/ post-application		None Detected 3/		

1/ Minimum detectable level = 0.004 mg/m^3
2/ Greenhouse was vented for two hours prior to sampling.
3/ Minimum detectable level = 0.002 mg/m^3

B. Permethrin: 0.05 lb AI/10,000 ft

Hours Post Application	A	B	C	D
		mg/m^3		
Pre-application		None Detected 4/		
1 to 2 Hours post-application	0.826	0.688	0.611	0.659
2 to 3 Hours post-application	0.433	0.671	0.666	0.584
13.5 to 14 Hours post-application	0.021	0.037	ND 5/	0.015
16 to 17 Hours post-application 7/		None Detected 6/		

4/ Minimum detectable level = 0.010 mg/m^3
5/ Minimum detectable level = 0.007 mg/m^3
6/ Minimum detectable level = 0.004 mg/m^3
7/ Greenhouse was vented for two hours prior to the sample

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APPENDIX I

Pesticide, Range of Application Rates and Commodity Treated for Monitored Applications

Pesticide (Formulation)	lbs AI/100 gal	Approximate lbs AI/Acre	Commodity
Benomyl (WP)	0.5	1.0	Carnations
Captan (WP)	0.75 - 1.25	1.88 - 5.0	Carnations Roses
Chlorothalonil (L)	1.05	2.4	Carnations
Endosulfan (WP, EC)	0.5 - 1.0	1.25	Carnations Chrysanthemums Cyclamen
Fluvalinate (L)	0.5 - 0.10	0.03 - 0.15	Carnations Gerbera Daisy
Methomyl (SP)	0.34 - 0.45	2.03 - 2.70	Chrysanthemum
Methyl Parathion (ME)	0.25 - 0.50	0.40 - 2.17	Chrysanthemum
Oxamyl (L)	0.50	2.17	Chrysanthemum
Permethrin (EC)	0.20	NA	Chrysanthemum
Triforine (EC)	0.15 - 0.23	0.45 - 0.63	Roses

EC = emulsifiable concentrate
L = liquid
ME = microencapsulated
SP = soluble powder
WP = wettable powder
NA = not available

APPENDIX III

Air Sampling Media

Pesticide	Filter	Sorbent Tube
Benomyl	GFF-AE	XAD-4
Captan	GFF-A or AE	XAD-4
Chlorothalonil	GFF-A	Chromosorb 102
Endosulfan	GFF-A	Chromosorb 102
Fluvalinate	GFF-A	Chromosorb 102
Methomyl	GFF-A or AE	Chromosorb 102
Methyl Parathion	GFF-AE	XAD-4
Oxamyl	GFF-A	XAD-4
Permethrin	GFF-AE	Chromosorb 102
Tritorine	GFF-A	XAD-4

Glass Fiber Filter A 0.3 um, SKC #225-6
Glass Fiber Filter AE 0.3 um, SKC #225-7
Chromosorb 102 resin, SKC #226-49-23-102 and #226-49-21-102
XAD-4 porous polymer resin, SKC #226-30-11-04